Why are Scots pines dying in the Swiss Rhône valley?

Stefan Hunziker[1]*, Michael Begert[2], Simon C. Scherrer[2], Andreas Rigling[1,3], Arthur Gessler[1, 3]

* stefan.hunziker@wsl.ch

[1] Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland [2] Federal Office of Meteorology and Climatology MeteoSwiss, Zurich, Switzerland
[3] Institute of Terrestrial Ecosystems, ETH Zurich, Zurich, Switzerland

1. Motivation

- Pronounced defoliation and mortality events occurred in the Swiss Rhône valley since the 1990s
- Previous studies identified drought as the main responsible factor
- However, **the specific drivers causing the observed spatio-temporal dieback patterns are still not well understood**

2. Data and methods

- Defoliation estimations of **four monitored forest plots**
- Parameters and indices derived from atmospheric variables from **20 meteorological stations**
- Further observational data included (remote sensing, soil moisture measurements, etc.)
- Comprehensive approach combining various analyses such as trend estimation, sensitivity analysis and multiple regression

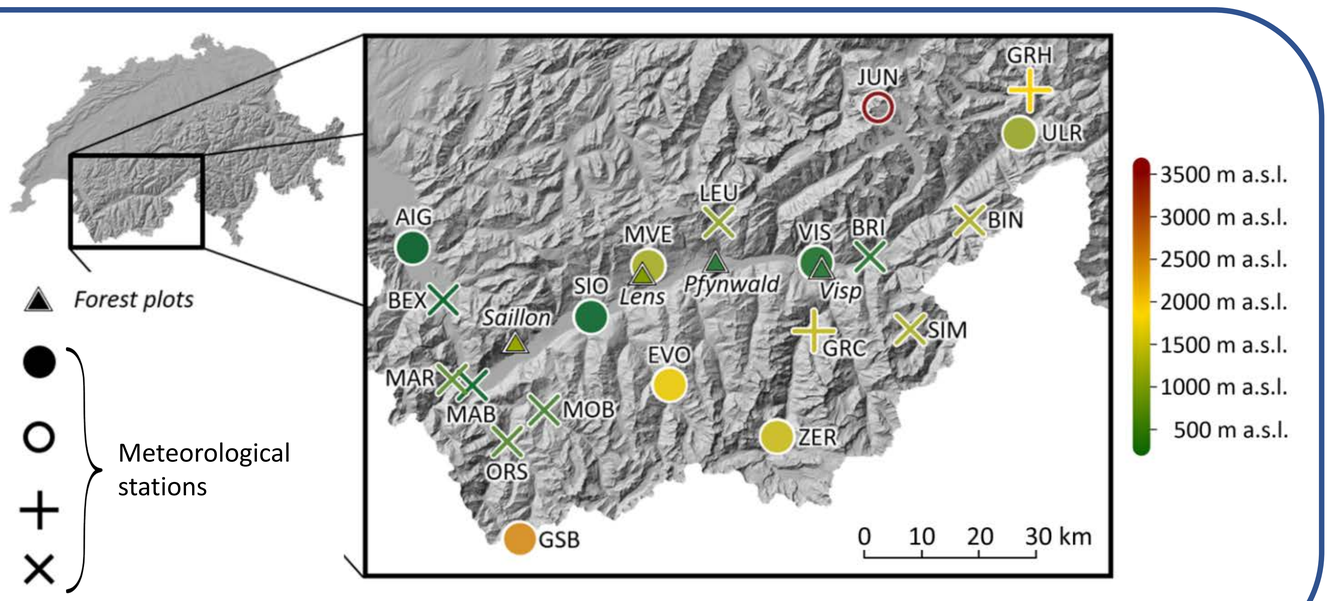

Figure 1. Overview of the study area (abbreviations of the meteorological station names are shown)

3. Scots pines are declining at lower elevations

- Scots pines have been declining at lower elevations in Visp (ca. 695 m a.s.l.) and Pfynwald (ca. 615 m a.s.l.), but no clear tendency is found at higher elevations in Lens and Saillon (>1000 m a.s.l.)
- **Defoliation and mortality in Visp** (annual defoliation increase of 5.7% and yearly mortality rate of 7%) **is characterized by four pronounced events, whereas the decline in Pfynwald occurred slower and more gradually** (annual defoliation increase of 1.5% and yearly mortality rate of 1.7%)

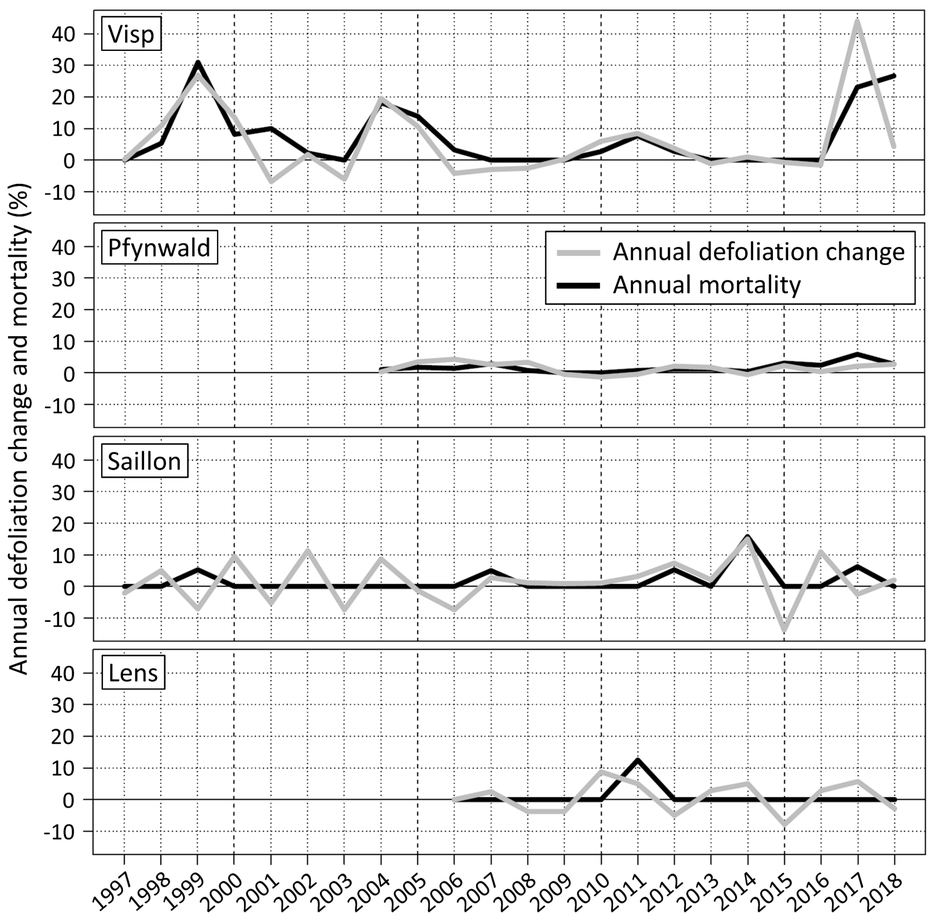

Figure 2. Annual defoliation change and mortality on the monitored forest plots

4. The climate in the Rhône valley shifted to drier conditions

- Strongest changes occurred at lower elevations
- **The increase of the reference evapotranspiration from 1981 to 2018 clearly exceeds the year-to-year variability, whereas precipitation is dominated by a pronounced year-to-year variability**
- The increased atmospheric water demand prolonged and intensified the period of very low soil moisture between summer and autumn

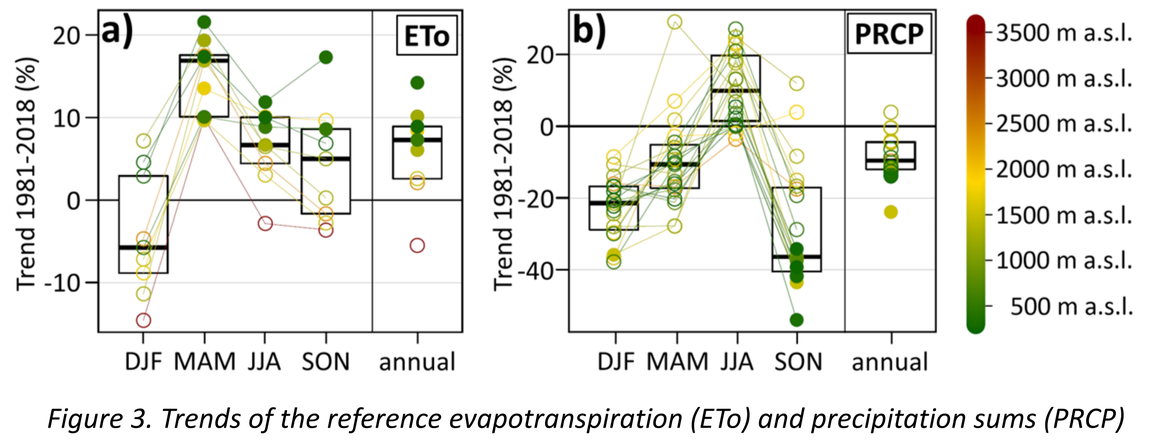

Figure 3. Trends of the reference evapotranspiration (ETo) and precipitation sums (PRCP) in winter (DJF), spring (MAM), summer (JJA), autumn (SON) and on annual time scale

5. Summer to early-autumn precipitation anomalies drive mortality and defoliation events

- **Anomalies of July to September precipitation intensity and frequency explain 62% of the following defoliation change** in Visp
- Pathogen infestation (around 1999) and spring frost (2017) intensified the severity of dieback events
- A high amount of severely damaged trees (≥75% defoliation) results in prolonged mortality after the peak of an event as these trees passed a "point of no return"

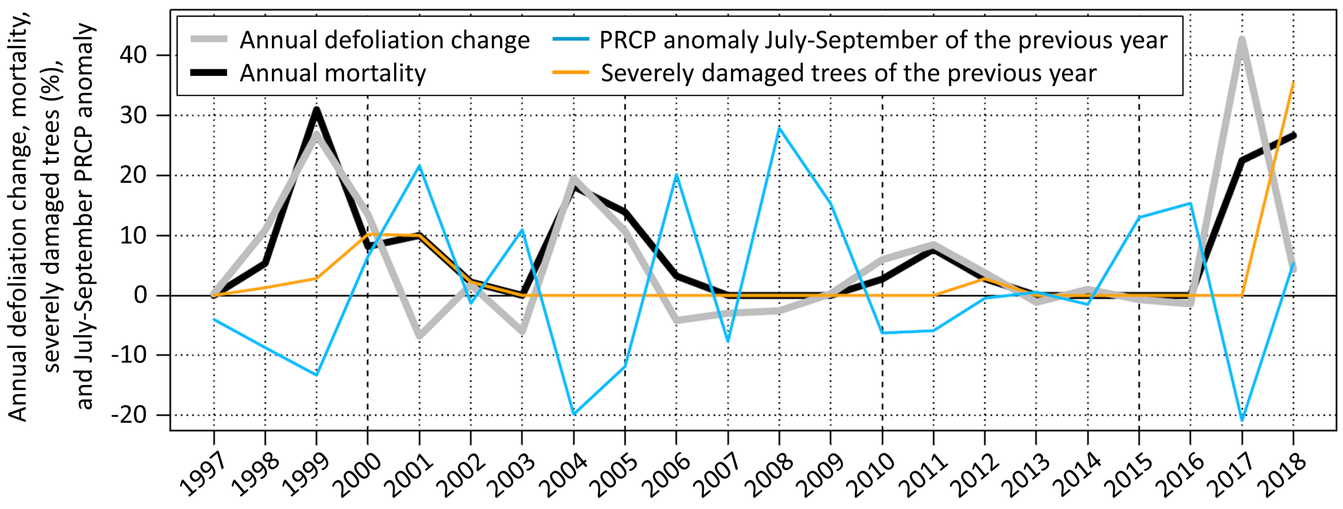

Figure 4. Annual defoliation change, mortality, July to September precipitation sums (PRCP) anomalies and the fraction of severely damaged trees in Visp

6. Local precipitation characteristics explain spatial dieback patterns

- **The region with the lowest 20th percentile of July to September precipitation around Visp matches the area most affected by dieback events**
- Considering climate projections for the next decades, it seems likely that Scots pine dieback events will occur in larger areas in the Rhône valley

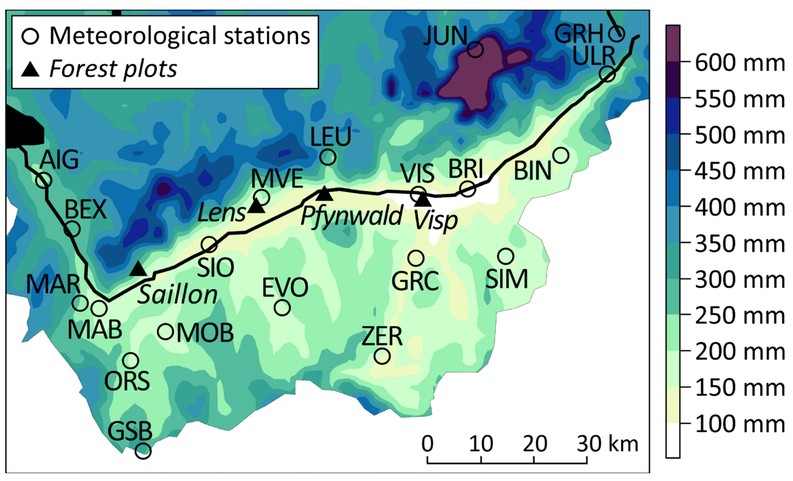

Figure 5. Spatially interpolated 20th percentiles of July to September precipitation sums

7. Conclusions

Climate conditions shifted to drier conditions (mostly due to increasing evapotranspiration)

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Period of very low soil moisture between summer and autumn prolonged and intensified

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Scots pines have become dependent on substantial precipitation events in this period of the year

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In regions with low July to September precipitation, **clearly negative anomalies cause defoliation and mortality events**